How Can We Explain Evolutionary Relationships among Species?

hhmi | BioInteractive

Activity
Educator Materials

OVERVIEW

In this inquiry-based activity, students engage in science practices to figure out ways environmental factors drive the natural selection and adaptation of Galápagos finches. This activity is based on content covered in the short film *The Origin of Species: The Beak of the Finch*. Instead of front-loading information from the film, the activity guides students through "figuring out" the key concepts first. Students make observations, analyze data, search for patterns and cause-and-effect relationships, construct arguments, and make predictions about the evolution of finch populations.

This activity is meant to be given to students in separate parts so that they can focus on figuring out one part before receiving the next. It is not recommended to provide all parts of the "Student Handout" as a packet together.

- In **Part 1**, students sort cards of different finch species based on their traits. They reflect on how these traits may impact survival and reproduction, and what they might reveal about evolutionary relationships among species.
- In **Part 2**, students use photos and a clip from the film to make more sense of the phenomenon.
- In **Part 3**, they analyze spectrogram (song pattern) data to identify and interpret patterns.
- In **Part 4**, they analyze genetic data and synthesize multiple lines of evidence to support claims about how the finches have diverged into the 13 species they have sorted.
- In the optional **extension**, students can transfer what they've figured out to the speciation of anole lizards.

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Certain traits affect an individual's ability to survive and/or reproduce in its environment.
- Versions of traits that help an individual survive/reproduce tend to become more common over generations, leading to evolutionary change.
- When two groups in a population become reproductively isolated, the groups can diverge into distinct populations with measurable differences, as their traits change in different ways. Over many generations, a species can ultimately diverge into two distinct species.
- Multiple lines of evidence — including physical traits, behavioral traits, and genetic data — can be used to study evolutionary relationships among species.

STUDENT LEARNING TARGETS

- Use evidence from observations to make claims and construct arguments about the evolution of Galápagos finches.
- Use data to make predictions about the evolutionary relationships among finch species.
- Obtain, evaluate, and communicate information regarding how evidence can change thinking about scientific phenomena.

PRIOR KNOWLEDGE

Students should have a basic understanding of:

- trait inheritance and variation (i.e., traits can be passed from one generation to the next, and some trait variations increase individual survival/reproduction in a particular environment)
- adaptations, selection, and selective pressure
- speciation and reproductive isolation
- interpreting DNA sequences
- evolutionary relationships (i.e., what it means to be "closely related" in evolutionary terms)
- interpreting evolutionary tree diagrams

MATERIALS

- copies of the "Student Handout" (distribute each part separately)
- one set of "Finch Species Cards" (13 cards) per student team
- access to video clips
  - for the main activity: Clip 1, Clip 2, Clip 3
  - for the extension: Extension Clip 1, Extension Clip 2, Extension Clip 3
- scissors (if using printed cards)
- camera or smartphone (optional, if you would like to take photos of the card groupings)

TEACHING TIPS

Before the Activity

- Print or electronically share files for the "Finch Species Cards" from the activity webpage.
  - A PDF file is provided as a printable option. Make sure to print the cards double-sided, so that each card has pictures of birds on one side and a graph on the other. Cut out the cards ahead of time, or have students cut them out.
  - Individual card images (JPGs) are provided in the "Card Images" ZIP file. You can use a virtual whiteboarding or collaboration software (e.g., Google Jamboard, Miro) in which students can move and annotate card images.
- Decide how students will access the video clips (links provided in the "Student Handout" in the "Materials" section above). This can be done in different ways to meet teacher and student needs. For example, you can:
  - Project and view each clip as a class. Give students time to answer the questions before moving to the next part.
  - Allow students to view the videos and answer the questions at their own pace.
- All clips are from the film *The Origin of Species: The Beak of the Finch*. Do *not* show the film in its entirety until after students have finished the entire activity.
  - Also be careful about saying the name of the film. It's important not to reveal the beak as a focus too early, since students will need to discover this for themselves through the activity.
- Students can work in teams of three or four for most of the activity. Give each *team* one set of cards (13 cards) and each *student* their own copy of the "Student Handout."
- Distribute each part of the "Student Handout" separately. Students should receive the next part only after they have completed each previous part. It is not recommended to give students all parts of the handout at once.

During the Activity

- Students can write observations and answers to the questions in the "Student Handout" or in other places (e.g., in notebooks, on separate paper, or in an online document).
- You may want students to take photos of their card groupings (or find another way to record the groupings) at various points, so that they can revisit them later.
- Each time students sort or re-sort their cards, you could ask them to view the card groupings of other teams and ask questions or provide feedback.
  - If you incorporate peer review at these points, include guidance for how you would like students to provide their feedback. For example, you could have them give constructive comments to or ask clarification questions of their peers.
- Students may revise their work at different points in the activities. It may be useful to have them use different colors or markings to indicate revisions.
- In **Part 1**, students' lists of traits will likely vary. However, lead students with questions if they do not include "beaks" as a trait. The goal is to lead students to beaks during Parts 1 and 2 of the activity without giving it away.
- In **Part 3**, you may want to familiarize students with spectrograms by having them view and listen to examples from Macaulay Library. Enter the name of a finch species in the search bar. On the search results page, select the "sound" icon on the top left to show related spectrograms. You may need to show students how to search or show examples to the whole class.

Clarifications and Caveats

- Make sure students understand that each card represents a different finch species, *not* different individuals of the same species. The species correspond to the card numbers as follows:
  1. woodpecker finch
  2. large ground finch
  3. medium tree finch
  4. mangrove finch
  5. sharp-beaked ground finch
  6. vegetarian finch
  7. warbler finch
  8. small ground finch
  9. large cactus finch
  10. small tree finch
  11. large tree finch
  12. medium ground finch
  13. cactus finch

Supplements and Extensions

- After students finish the main activity, you may want to show the film *The Origin of Species: The Beak of the Finch* from start to finish.
- The extension at the end of the "Student Handout" is an optional transfer task where students apply what they've figured out to the speciation of anole lizards.
- After completing the activity, students can move on to other BioInteractive resources to continue their learning around natural selection and speciation. For example:
  - The Click & Learn *Sorting Finch Species* is an interactive resource with some similarities to this activity. Students sort the same 13 finch species based on appearances and songs.
  - The activity "Beaks as Tools: Selective Advantage in Changing Environments" uses a hands-on model to simulate the effects of different beak sizes.
  - The *Lizard Evolution Virtual Lab* has students explore the evolution of anoles through data collection and analysis.

ANSWER KEY

PART 1: Analyzing Data Based on Careful Observations

1. Go through the cards and list the different traits you observe from the finch pictures. You can include both **physical traits** (how the finches appear in the pictures) and **behavioral traits** (what the finches are doing in the pictures).
   Student answers will vary. Examples of physical traits may include size, color, dimorphism (different forms within the same species), and beak shape/size. Examples of behavioral traits may include whether the finches perch on branches or stand on the ground.

2. Once your team has agreed on a list of traits, list each trait in the leftmost column of the table below. Add an "X" under each species that has that trait.
   Student answers will vary depending on the traits they chose.

3. Next, you will group the cards based on which species you think are more closely related. In evolutionary terms, species being "closely related" means they share a recent common ancestor. Before moving the cards:
   a. In your own words, explain what it means for two species to share a recent common ancestor.
      Students' understanding of this concept will vary depending on their prior knowledge of evolution; provide clarification and support as needed.

   b. Explain how you can use the information in your table above to help group the finches as seen on the cards.
      Students may expect more closely related species to share a greater number of traits.

4. Now group the cards based on which species are more closely related. Explain how you chose your groupings below, including the reasoning for your decisions.
   Students should describe the method/traits that they used to group their cards. If they expect closely related species to share traits, for example, they may group species that share more traits together.

5. Predict which traits would be most important for increasing an individual finch's chance of survival (living longer) or reproduction (having more offspring). Categorize these traits in the table below. Next to each trait, explain why you put it in that category.
   Student answers will vary. They will likely list "beaks" in the "survival" category. Beaks allow finches to access food, which increases their chances of survival.

6. Discuss your ideas for the previous question with other teams in your class, or as directed by your instructor.
   a. Based on your discussion, which trait seems most important to finch *survival*?
      Student answers will vary. If they do not answer "beaks" here, Part 2 will lead them there.

   b. Why would this trait be so important to finch survival?
      Students should connect the trait above to how it increases a finch's chance of survival.

7. How might traits that increase *individual* survival help reveal evolutionary relationships among *species*? Support your answer using evidence from what you have figured out so far.
   Students may recognize that these traits are often retained in species when they diverge into different species. Examining which species share these traits can help reveal evolutionary relationships.

PART 2: Making Sense of a Phenomenon

8. Record your observations of the seeds and finches below.
   Students may make observations about the shapes and relative sizes of the seeds and the finches' beaks.

9. Watch a video clip (Clip 1) to learn how these finches have been studied for the past several decades. Based on the clip and the images above:
   a. Which of the traits you listed in Part 1 is most important to finch survival?
   Student answers should include some aspect of beak structure/function.
   b. How would this trait help a finch survive?
   The beak impacts a finch's ability to consume the food available to them. Finches with beaks that can access the food can eat more easily, which increases their chances of survival.
10. Based on your observations of *the trait you picked in Question 9 only*, re-sort your finch species cards. Explain the criteria you used to determine your new groupings below. (If you did not change your groupings, explain why your original groupings were appropriate.)
    Students should explain why they grouped the finch species cards the way they did, whether they re-sorted them or not.
11. **Selective pressures** are factors that affect an individual's chance of survival or reproduction in its environment. How might selective pressures drive certain versions of the trait you picked in Question 9 to become more common over generations?
    Student answers will vary depending on their understanding of natural selection; provide clarification and support as needed. Selective pressures may include the availability of certain foods, such as seeds of a specific size. Finches with beaks that are better at accessing these foods are more likely to survive, reproduce, and pass similar traits on to their offspring. As a result, their beak types are likely to become more common over generations.
12. Do you think selective pressures on the trait you picked in Question 9 could lead to a population of one species becoming so different that they diverge into a new species? Provide reasoning that supports your answer.
    Student answers will vary depending on their prior knowledge. If students answered yes, they may explain how this situation could lead to reproductive isolation. These concepts will be explored more in the next part of the activity.

PART 3: Using Data to Determine Evolutionary Relationships

13. What do you think makes an individual reproduce *only* with others of its own species?
    Student answers will vary depending on their prior knowledge. They may include that species can distinguish the traits of their own species from others and respond only to individuals with those traits.
14. Watch another video clip (Clip 2) of scientists playing finch songs. Predict what happened in the experiment described at the end of the clip.
    Student answers will vary. They may suggest that only finches of the same species would respond to each finch's song.
15. Without changing your card groupings, flip your finch species cards over. The back of each card will have a graph like the ones shown in the video clip. This graph, called a **spectrogram**, represents a finch's song as a pattern of sound frequencies.
    a. Do the new data from the spectrograms support your current card groupings? Provide reasoning for your answer.
    Student answers will vary depending on their groupings. Their explanations will likely mention some of the patterns among the spectrograms and whether certain patterns are more similar.

b. Would you change any of your groupings with the new data in mind? Why or why not?
Student answers will vary depending on their groupings.

16. Using what you figured out in Parts 1 and 2:
    a. Describe any patterns you observe in both the songs (behavior) and the physical traits of these finch species.
    Students may find many different patterns in both songs and physical traits. With this in mind, it is important to view student predictions as part of the scientific process. For example, students may state that some finches with smaller beaks share some similarities in song patterns. This response may change when new information becomes available. Allow students to make and revise their predictions as needed, without penalizing them for being "wrong."
    b. Do these patterns help explain why finches of different species may not reproduce with one another? Provide evidence to support your answer.
    By this point, students will likely know that finch songs play a major role in their reproduction. Students may suggest that differences in the song patterns help finches recognize the song of their own species and not others.

17. Which of the traits you observed may keep different species of finches that live in the same place from mating with each other?
    Students' responses should connect to their reasoning. They will likely include the idea of finch's songs attracting only others of their own species.

18. Do finch songs aid more in the survival of the individual finches or more in their chances of reproduction? Provide reasoning for your answer.
    Student answers should include ideas about species only being attracted to/responding to members of the same species based on their song. Since a finch responds only to the song of its own species, this increases their chances of reproducing with individuals of the same species.

PART 4: Using Genetic Data to Determine Evolutionary Relationships

19. By making careful observations of the DNA sequences, explain how they could be used to better understand the evolutionary relationships among the different finch species.
    Students may recognize similarities, such as shared nucleotides, among the DNA sequences. The more similarities between two DNA sequences, the more related their species may be to each other.

20. Based on the new data shown by Figure 3, would you change your finch species groupings? Explain how the new data may allow you to revise your model.
    The evolutionary tree can provide a more precise map of likely evolutionary relationships that may not be as obvious from just physical and behavioral traits. Some students may have substantial changes to their groupings based on which traits they used.

21. How do you think DNA sequencing changed how we view the many different species on Earth?
    Answers may include that DNA sequencing provides a new way to identify evolutionary relationships among species, including relationships that are not as obvious from just physical and behavioral traits. For example, DNA evidence can give us a better idea of which species diverged from common ancestors.

22. Over the course of this activity, you observed different types of data, including images, spectrograms, and evolutionary trees based on DNA sequences. Why are multiple lines of evidence important when studying evolutionary relationships among different species?

Student answers may vary. They may include the idea that more closely related species may share more traits, so comparing physical and behavioral traits can be useful for getting a broad sense of which species may be related (without having to sequence every species, which may be more difficult or costly). Genetic evidence helps support the evolutionary relationships suggested by traits with more precision and certainty.

EXTENSION: TRANSFER TASK WITH ANOLE LIZARDS

1. Watch the first video clip (Extension Clip 1), which describes different anole species found on the islands of the Caribbean.
   a. Which traits that aid in the survival of anoles are under high selective pressure in their environments?
   Leg length, toepad size

   b. How are these traits similar to the finches' beaks?
   Similar to the finches' beaks, the anoles' legs and toepads are adapted to help them survive in their own environments. The length of an anole's legs and the size of its toepads help it live in its habitat. (For example, anoles living on the ground tend to have long legs for running, and anoles living in the canopy tend to have large toepads for climbing.) This is similar to how the structure of the finches' beaks helps them eat available foods.

2. Watch the second video clip (Extension Clip 2).
   a. Which trait in the anoles is similar to the finches' songs?
   dewlap (colored flap on the throat)

   b. How is this trait similar to the finches' songs?
   Dewlaps are used by anoles to attract mates, much like the songs of the finches. Anoles of the same species recognize the unique color/pattern of their dewlaps, much like the finches recognize the song of their own species.

3. Watch the third and final video clip (Extension Clip 3).
   a. How do traits you mentioned in the previous questions allow for anoles on each island to become different species?
   Anoles with different leg lengths and toepad sizes can live in different parts of the environment (e.g., on the ground vs. in trees), and they are less likely to meet and reproduce with anoles in different areas (reproductive isolation). Over many generations, populations of anoles in different areas can undergo enough changes to become different species.

   b. Why is genetic data so important for determining evolutionary relationships among species?
   Genetic data provides more precise and conclusive evidence about evolutionary relatedness. It can reveal relationships that may not be as obvious from just observing physical and behavioral traits.

REFERENCES

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CREDITS

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